Line, Trunk, Junctor, and Service Circuits for No. 1 ESS

By R. BIDDULPH, A. H. BUDLONG, R. C. CASTERLINE, D. L. FUNK and L. F. GOELLER, Jr.

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In the No. 1 electronic switching system, individual circuits are needed on a per-line, per-trunk, and per-call basis to provide an interface between the outside world and the centralized call processing equipment. These circuits, including digit transmitters and receivers, are characterized by simplicity and compactness, and are program controlled. This article discusses their electrical and mechanical design along with transmission properties and maintenance procedures.

I. INTRODUCTION

Centralization of memory and control, long a dominant trend in telephone switching, has come close to the ultimate in the No. 1 electronic switching system (ESS). Nevertheless, individual circuits are still required on a per-call and even per-line basis to match the widely variable outside world to the standardized "inside world" of the central processor.[1] These individual circuits, the line, junctor, trunk and service circuits, provide the subject matter for this paper.

It is obvious that the central processor must work at very high speeds if it is to take over all memory and control functions. Even though actual signals from customers and other telephone offices come in relatively slowly, the central processor must operate rapidly to divide its time among the many signals flowing simultaneously over thousands of lines and trunks. What may not be so obvious, however, is the way in which this centralization affects the circuits in contact with lines and trunks during the processing of calls. In No. 1 ESS, these circuits have been reduced to very simple configurations; each circuit performs only a few functions under program control,[2] and different circuits are connected as needed via the switching network.[3] Both flexibility and economy result.

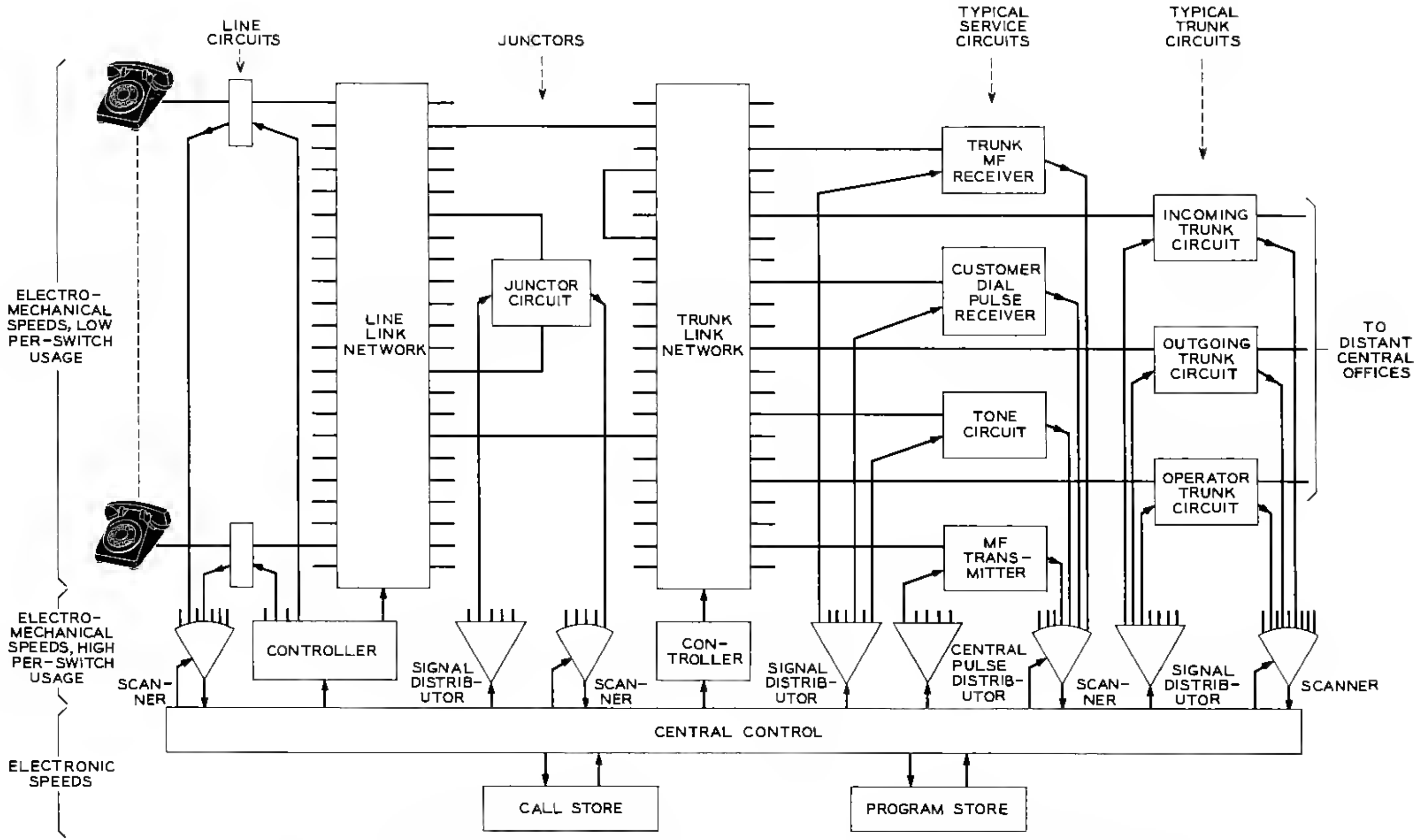


Fig. 1 — Block diagram showing relationship between line, trunk, junctor and service circuits and the rest of No. 1 ESS.

II. CIRCUITS DIRECTLY ASSOCIATED WITH CUSTOMER LINES AND TRUNKS

Fig. 1 shows the relationships between the various circuits associated directly with customer lines and trunks and the rest of No. 1 ESS. The status of customer lines and trunks is detected in the scanners by current-sensitive devices called "ferrod sensors" and transmitted to the central processor. The latter, consulting its memory and stored program, operates appropriate switching devices via signal distributors or central pulse distributors, depending on whether slow or fast action is required.[4] Interconnections are made via the networks, and the network controllers (rather than signal distributors) are used to operate switches in the line circuits.

It is important to note that ferrod sensors, although they behave in many ways like supervisory relays, perform no function other than current detection; they have no contacts and produce no circuit actions except indirectly via the central processor.

The scanners, signal distributors, central pulse distributors and network controllers act as input and output devices for the central processor. They require, however, additional circuitry to meet the variable conditions found on customer lines and trunks. Thus line, junctor, trunk and service circuits have been developed.

The line circuits shown in Fig. 2 are the simplest of these; they carry out the traditional functions of line and cutoff relays, supervising each customer line for originations and removing the sensing element to prevent its shunting the talking path. Carbon protector blocks, also shown as part of the line circuits, limit lightning surge voltages. In a way, there is no such entity as a line circuit in ESS, since the ferrod sensor is part of the line scanner, the cutoff relay is part of the network, and the carbon blocks are part of the protector frame. Nevertheless, it is convenient to refer to line circuits for purposes of exposition.

Next in complexity comes the junctor circuit, shown in Fig. 3. This circuit is used only during conversations between customers served by the same No. 1 ESS. Calling and called customers are connected to a junctor circuit via paths through line link network only (the trunk link network is not required, as can be seen from Fig. 1). Each junctor circuit contains two relays, labeled A and B. These are magnetic latching relays, pulsed operated or released by the signal distributor on command from the central processor.

Trunk circuits contain only a few more components than junctor circuits, but because more is required of them, their design is considerably more complex. They will be discussed in detail in the several sections

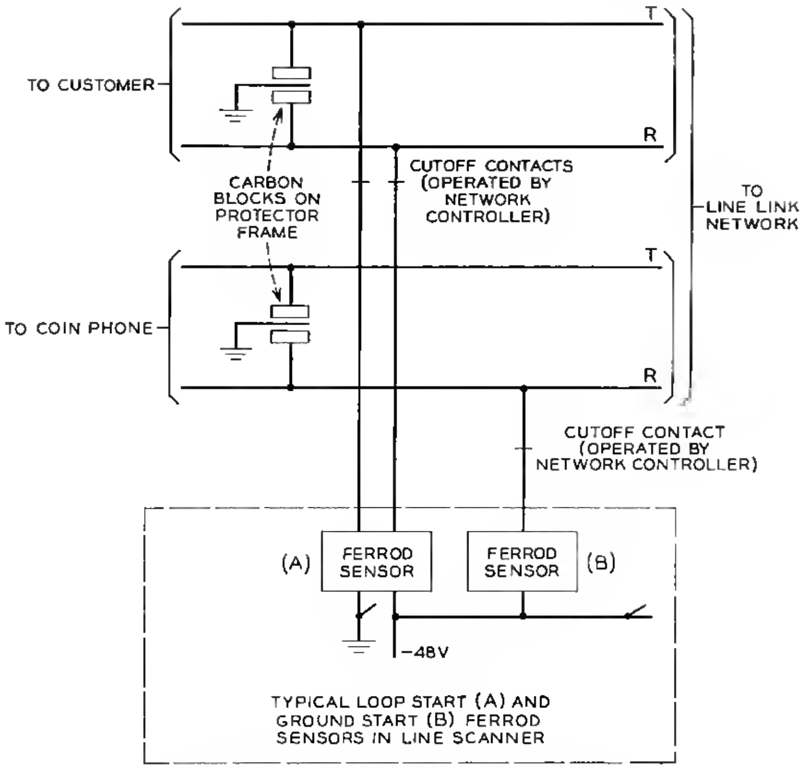


Fig. 2 — Typical loop start and ground start line circuits for sensing call originations and subsequently removing the sensor shunt.

which follow. At this point, however, it is necessary to emphasize the difference between a trunk and a trunk circuit. A "trunk" is a communication channel between two switching systems. It starts at the outgoing terminals of the switching network in the originating office and ends at the incoming terminals of the switching network of the terminating office.* As shown in Fig. 4, a trunk includes the transmission facility terminated in two "trunk circuits," one at each end. Traditionally, trunk circuits convert supervisory information (telephone on or off hook) from the distant central office into a form suitable for local use, and, conversely, convert local supervision to a form which can be transmitted in the opposite direction. Often, in present systems, current for the

* For transmission purposes, a trunk is measured between the outgoing network terminals of the originating office and the outgoing network terminals of the terminating office.

transmitter in local subsets is supplied from trunk circuits, digit pulsing features are included, and a variety of other functions are performed.

In No. 1 ESS, trunk circuits retain very few of these functions. Indeed, as can be seen in Table I, coin control, ringing, tone application and the like are *not* provided in trunk circuits but come from "service circuits" to which lines and trunks can be connected as required via the line and trunk link networks. This use of the networks is possible only because of the speed with which the networks and the central processor can work together to find, remember and set up paths.

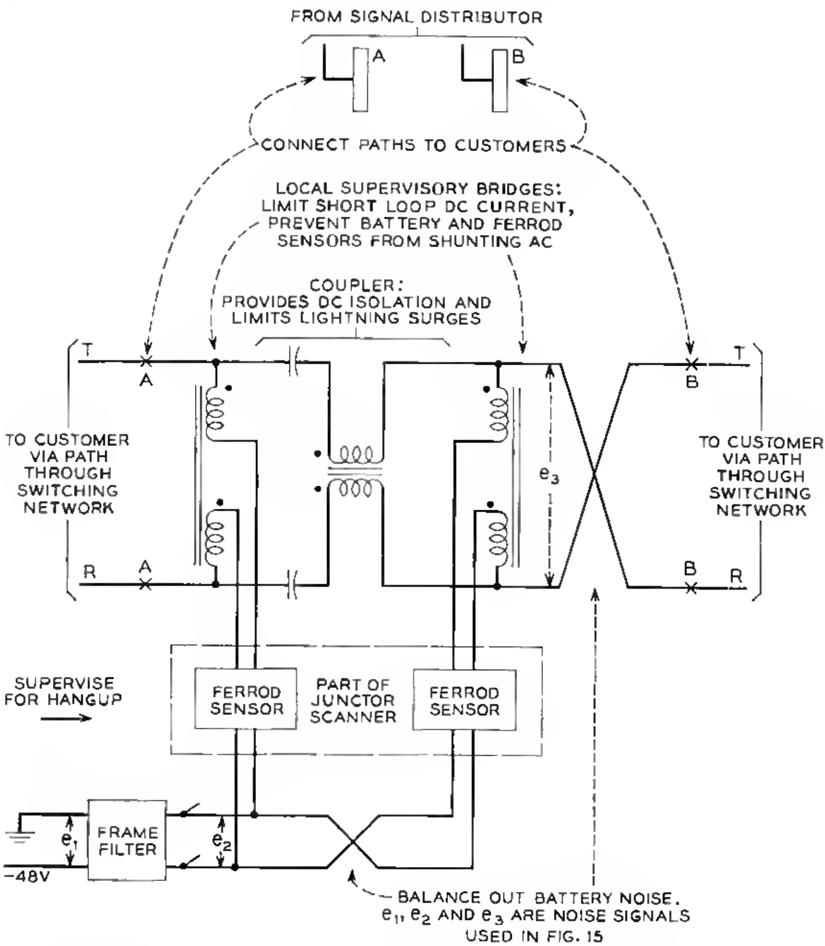


Fig. 3 — Junctor circuit used during conversations between customers served by the same ESS.

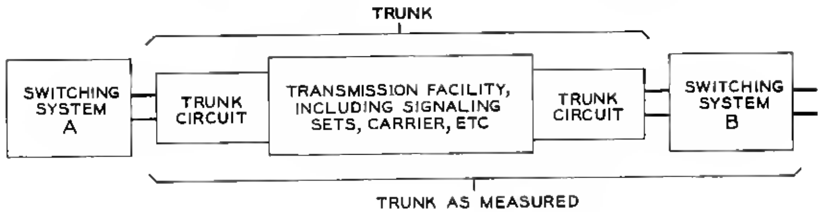


Fig. 4 — Relationship of trunk circuits to a trunk.

The advantages of this approach are many: no distinction between coin and noncoin trunks need be made, since coin control is not a function of the trunk circuit. Different types of ringing can be applied to different lines on a class basis. This permits sensitive trip relays with greater range to be used wherever possible, while less sensitive trip relays are retained for the remaining lines. New types of ringing can be added as desired, since, unlike earlier systems, no changes need be made on a per-trunk basis. Digit transmitters and receivers for signaling distant offices can be arranged in single groups by pulsing type, giving the usual

Table I — General Trunk Circuit Functions and No. 1 ESS Circuits which Perform These Functions

Function	Performed in No. 1 ESS by
Supervision	Scanners
Battery feed, dc isolation Transmission to local lines Transmission, trunk-to-trunk Path continuity check through line and trunk link networks Lightning surge protection for line and trunk link networks Make and break current through line and trunk link networks	Talking circuits, including trunk, junctor, and conference circuits
Signaling Ringing Returning tones Coin control Foreign potential detection Certain other tests	Service circuits including digit transmitters and receivers and ringing, tone, coin control, and test circuits
Timing Sequencing Memory (including digit storage) Charging	System control, including central control, call processor, call store, and program store

TABLE II—LINE, TRUNK AND SERVICE CIRCUITS USED IN PROCESSING TELEPHONE CALLS IN NO. 1 ESS

Function	Intraoffice Call	Outgoing Call	Incoming Call
Detect origination	scanner via line ckt.	scanner via line ckt.	scanner via incoming trunk ckt.
Foreign potential test, party test, return dial tone	customer dial pulse receiver	customer dial pulse receiver	—
Obtain digits of called party	customer dial pulse receiver	customer dial pulse receiver	dial pulse, revertive, or multifrequency receiver as required
Outpulse digits of called party	—	dial pulse, revertive, panel call indicator or multifrequency transmitter as required	—
Return busy, overflow, or audible ringing tone to calling customer	tone circuit	circuits in distant office	tone circuit
Send ringing signal to called customer, detect answer and trip ringing	ringing circuit	circuits in distant office	ringing circuit
Provide talking current, transmission circuit	junctor circuit	outgoing trunk circuit	incoming trunk circuit
Supervise for hang-up	scanner via junctor circuit	scanner via outgoing trunk ckt.	scanner via incoming trunk ckt.

advantages of one large group over several smaller groups. Further, the type of pulsing on any trunk can be altered by a simple program change, because any transmitter or receiver can be used with any trunk, depending only on a translation option.

Table II shows how various line, junctor, trunk and service circuits are used to process typical telephone calls in No. 1 ESS. Several circuits and several network connections may be in simultaneous use on a single call.[3]

III. THE DESIGN OF TRUNK AND SERVICE CIRCUITS

3.1 *Switching Design*

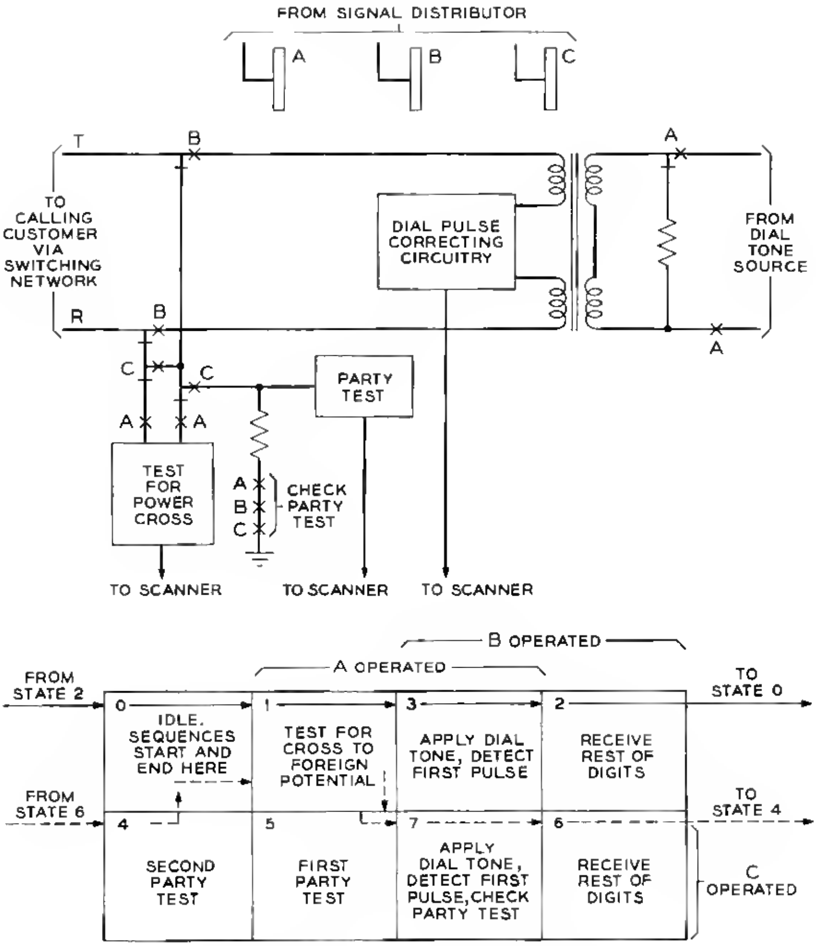
Each trunk and service circuit in No. 1 ESS carries out some of the functions listed in Table I. However, within any one circuit, association of one function with a particular switching device is uneconomical. Instead, a given function is related to one particular state of a group of switches. The Karnaugh map[5] is a design tool well suited for such situations; it also aids in circuit explanation.

An example of the technique is afforded by a somewhat simplified version of the customer dial pulse receiver (CDPR) circuit as shown in Fig. 5. The CDPR is a service circuit used to correct distortion on pulses generated by customer dials and to repeat the improved dial pulses to the scanner. It performs the additional functions of testing for foreign potentials crossed to outside plant conductors, party identification on two-party lines, return and removal of dial tone, check of continuity through the switching network, and cut-through or the making and breaking of current flowing in each connection.

Matching circuit functions to circuit states must be done in such a way that (a) a minimum number of states is required and (b) the transitions from state to state are made as simply as possible. The solution for the CDPR is shown in Fig. 5 along with the circuit. Three magnetic latching relays, A, B and C, are operated by the signal distributor to provide eight states.

For minimum delay as well as minimum relay wear, the operation or release of just one relay takes the circuit from one useful state to the next. Two arrows, one solid and one dotted, show the two principal state sequences. For individual lines, the A relay is operated to put the circuit in the power cross test state. If no crosses to a foreign potential are detected, the B relay is operated to connect dial tone and the pulse-correcting circuitry. A is released to remove dial tone while leaving the pulse-correcting circuitry connected, and B is released to make the circuit idle when all digits have been received from the customer. Only four signal distributor operations suffice.

It must be remembered, however, that the scanner extracts information from the circuit at a high enough sampling rate to detect all dial pulses and that the central processor counts and stores digits, times for interdigital periods, translates route information, etc. The simplicity of the CDPR is possible only because of the versatility of the central processor.



SEQUENCE	STATE NUMBERS
FOR INDIVIDUAL LINE	0-1-3-2-0
FOR TWO-PARTY LINES	0-1-5-7-6-4-0

Fig. 5 — Simplified circuit and Karnaugh map for customer dial pulse receiver, illustrating association of functions with states rather than individual relays.

The sequence for two-party lines (dotted arrow) starts with the power cross test state as before, then, on operation of the C relay, enters the first of two party-test states. Dial tone is returned after the party test is completed, and while dial tone is being transmitted the party-test circuit is checked for proper operation. Dial tone is removed after the customer starts dialing. Then, after all digits are received, the second party test is performed. Finally, the circuit is returned to its idle state. Only six signal distributor operations are required.

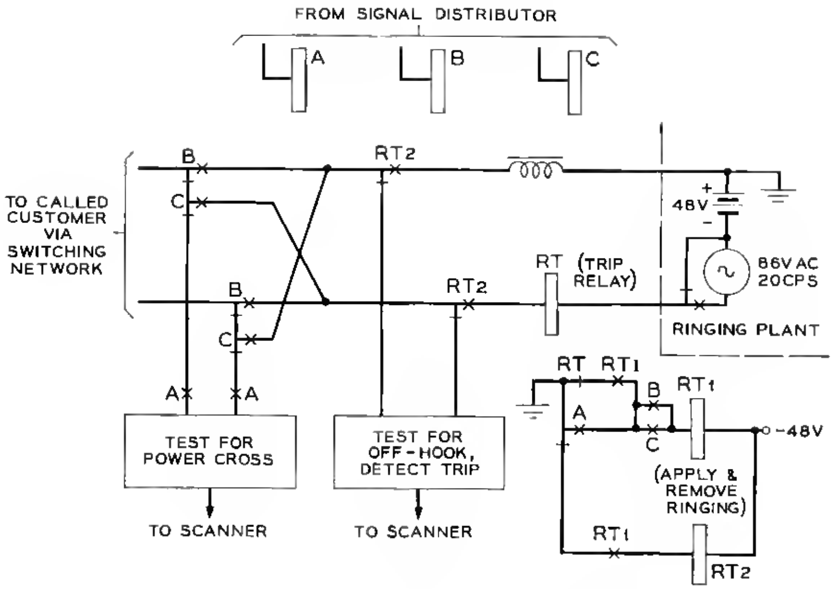
As a convenient method of keeping track of circuit states, each relay operated by the signal distributor is given a "weighting" number: A = 1, B = 2, and C = 4.* In any given state the weighting numbers of each operated relay are added together to produce the state number. Thus the two sequences in the customer dial pulse receiver described above would be 0-1-3-2-0 and 0-1-5-7-6-4-0 respectively. It must be emphasized that only one relay can be operated or released by a signal distributor at any one time. Thus sequences such as 0-3 are impossible. This constraint can be seen easily if one "walks through the map" as in Fig. 5 from one adjacent square to another, keeping in mind that opposite edges of the map are considered adjacent (as in the transition 2-0, where the B relay is released).

Figs. 6, 7 and 8 show three additional service circuits with their associated maps and typical sequences. Ringing, coin control potentials, and tones can thus be applied to any customer line in the office independent of the circuits used for conversation.

3.2 *Transmission Design*

Fig. 3 shows the transmission configuration used for intraoffice calls and also indicates the functions of some of the components. When a call is destined for a distant office, the somewhat more complex transmission circuit of Fig. 9 is employed. This latter circuit uses different coil resistances to control trunk supervisory currents, provides improved longitudinal balance, and also permits an impedance transformation when necessary. A nonconventional feature is use of an inductor-resistor network which substantially reduces the variation of impedance of customer lines with frequency as seen by the interoffice transmission facility. Although this network should be considered part of the customer loop to which the trunk is attached in any given conversation, the improved return loss it provides is useful only in transmission paths containing gain. Thus it is placed in trunk circuits for economic reasons.

* When more than three relays are required, octal notation is used: D = 10, E = 20, F = 40, G = 100, H = 200, etc.



B OPERATED

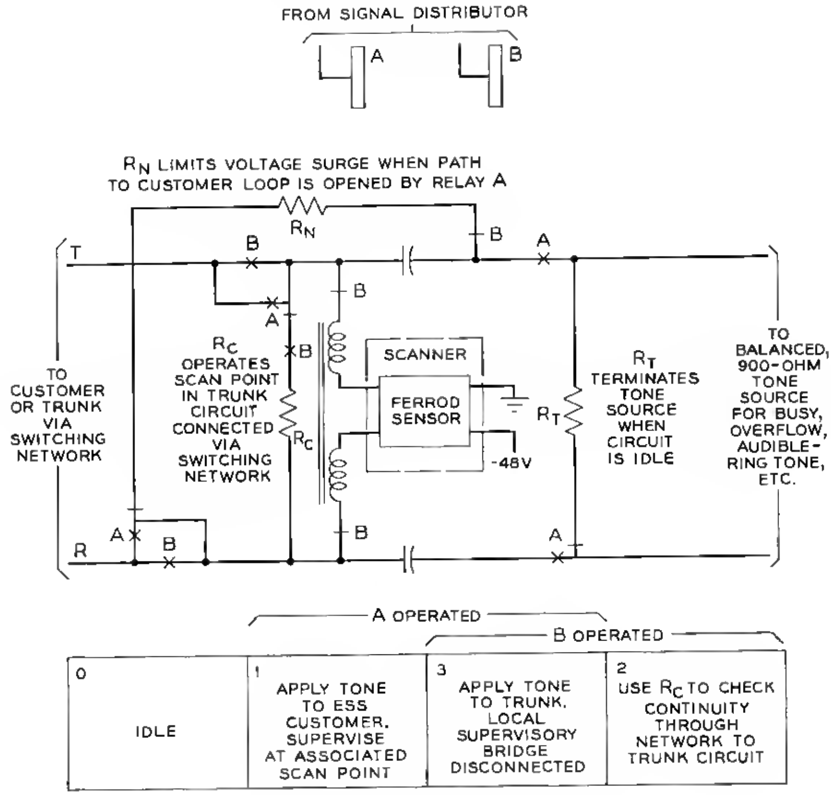
A OPERATED

0 IDLE	1 TEST FOR CROSS TO FOREIGN POTENTIAL	3 TEST FOR OFF-HOOK	2 RING INDIVIDUAL AND RING-PARTY CUSTOMERS	
4 RING TIP-PARTY CUSTOMERS	5 TEST FOR EXCESSIVE TIP SIDE LEAKAGE	7 NOT USED	6 NOT USED	C OPERATED

SEQUENCE	STATE NUMBERS
FOR INDIVIDUAL AND RING-PARTY CUSTOMERS	0-1-3-2-0
FOR TIP-PARTY CUSTOMERS	0-1-5-4-0

Fig. 6 — Simplified circuit for applying ringing to certain classes of lines.

Fig. 10 shows the effects of this simple network on mean loop impedance, and Fig. 11 illustrates the increased mean return loss resulting from its use. Fig. 12, based on a comprehensive survey, shows how this improved echo and singing return loss is distributed over present Bell System loops.[6] This increase in customer loop return loss can be utilized in various ways; in particular, some increase in gain can be permitted on

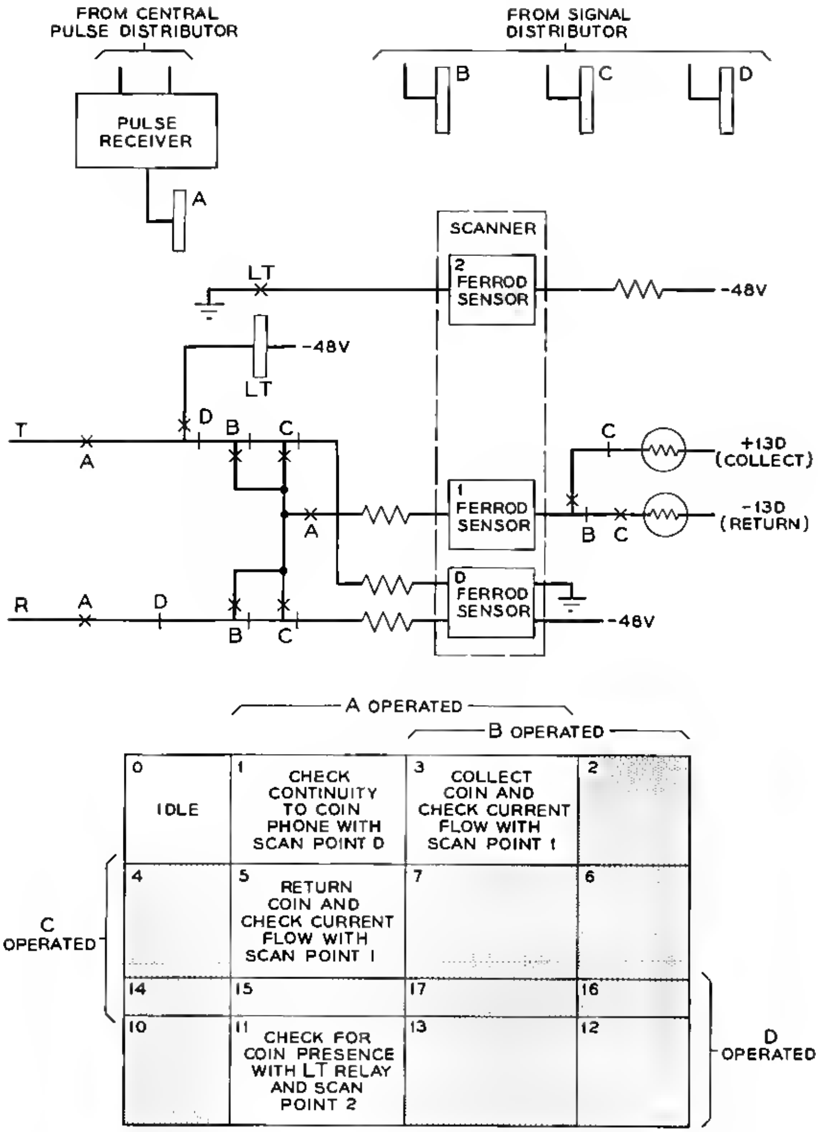


SEQUENCE	STATE NUMBERS
FOR LOCAL CUSTOMERS	0-1-0
FOR TRUNKS	0-2-3-2-0

Fig. 7 — Tone circuit.

toll connecting trunks. Although not shown on Fig. 9, idle circuit terminations are provided to assure repeater stability.

In a tandem connection, an incoming trunk must be joined to an outgoing trunk. Under such circumstances, customer loop compensation is omitted. Further, the local supervisory bridges in both the incoming and outgoing trunk circuits are switched out (as discussed in Section 3.3) to produce the equivalent of exactly one transmission circuit. The insertion loss of this tandem circuit varies less than 0.4 db between 200



SEQUENCE	STATE NUMBERS
COIN COLLECT	0-1-3-1-0
COIN RETURN	0-1-5-1-0
COIN TEST	0-1-11-1-0

Fig. 8 — Simplified coin control circuit; because of very short holding time, central pulse distributor is used to speed up operation.

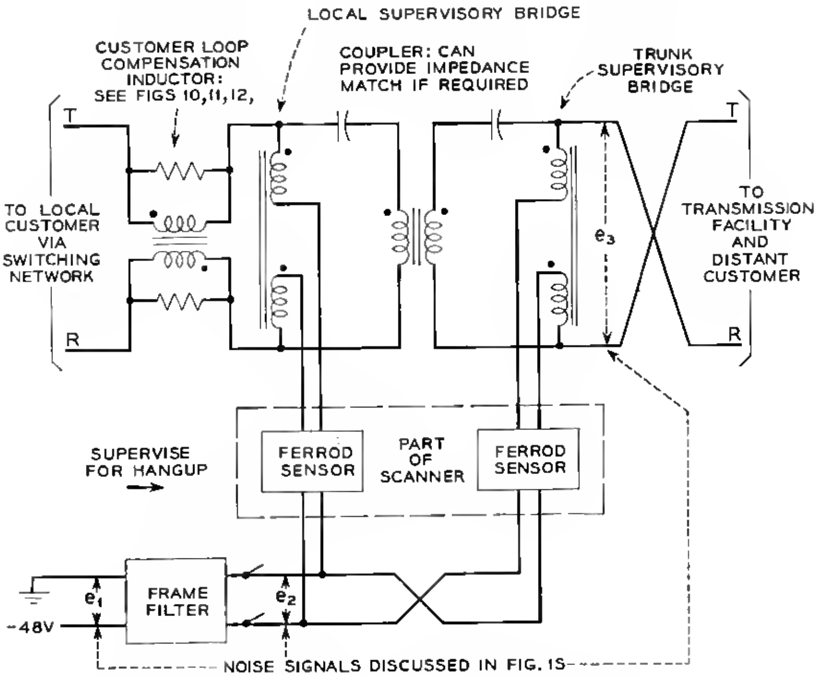


Fig. 9 — Transmission elements of trunk circuits: as shown, configuration corresponds to an incoming trunk circuit.

and 5000 cps, with a 1000-cps flat loss of 0.3 db. The structural echo return loss (not including switching network conductors)* is 36 db measured between 900 ohm + 2.14 mf terminations.

Fig. 13 illustrates the longitudinal balance characteristics of trunk and junctor circuits. Balance of each conductor relative to ground is necessary to reduce longitudinally induced noise from power lines and earth potentials, and to reduce battery noise and crosstalk coupled by common ground impedances. Individual components are designed to provide a longitudinal balance for the entire trunk circuit of at least 55 db when measured as shown. The measuring circuit simulates representative field situations. Both inductive and resistive components of the supervisory bridge inductors relative to their midpoints must be carefully controlled, and a balanced configuration is required in both transformer and blocking capacitors.

* Structural return loss of a trunk circuit is defined as the return loss of a trunk circuit terminated in a reference network measured against an identical reference network.

Because of the compact equipment arrangements in trunk and junctor circuits (to be discussed in Section V), great care is exercised to reduce crosstalk coupling. Special efforts have been made to reduce impulse noise in one circuit produced by relay operations in the second circuit on the same equipment unit. Audio-frequency crosstalk has also received attention; Fig. 14 shows the attenuation of voice-frequency crosstalk between a pair of such circuits.

Battery noise and common battery impedance present another disturbance to transmission. Fig. 15 shows how the frame battery filter reduces such noise; also shown is the effect of the well-known transposition which causes any remaining noise introduced into the line side to cancel that introduced into the trunk side.

In addition to the transmission properties of trunk and junctor cir-

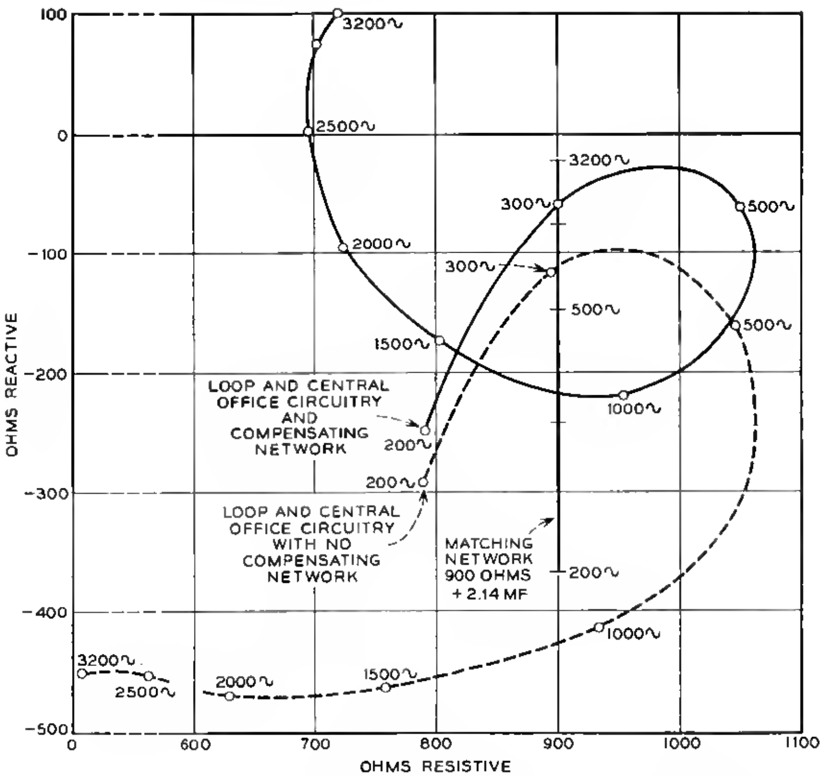


Fig. 10 — Effect of compensating network on mean input impedance of Bell System customer loops.

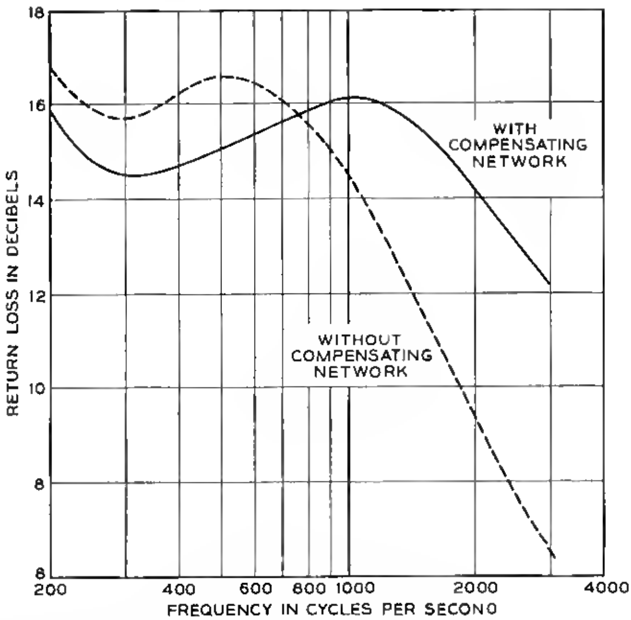


Fig. 11 — Effect of compensating network on mean customer loop return loss matched against 900 ohms + 2.14 mfd.

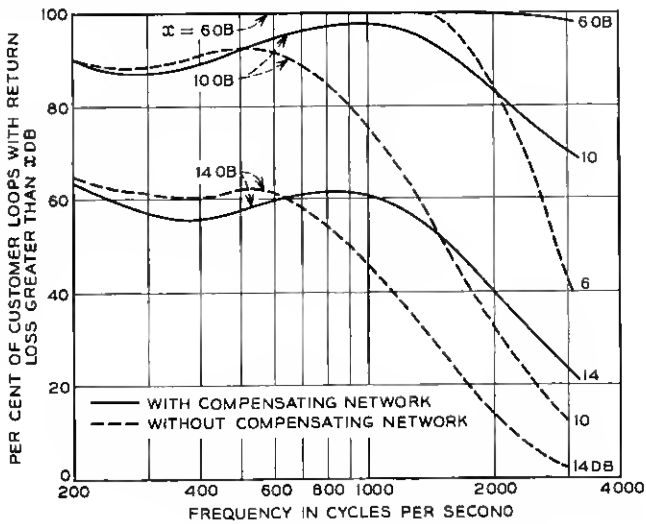


Fig. 12 — Effect of compensating network on return loss distribution of customer loops.

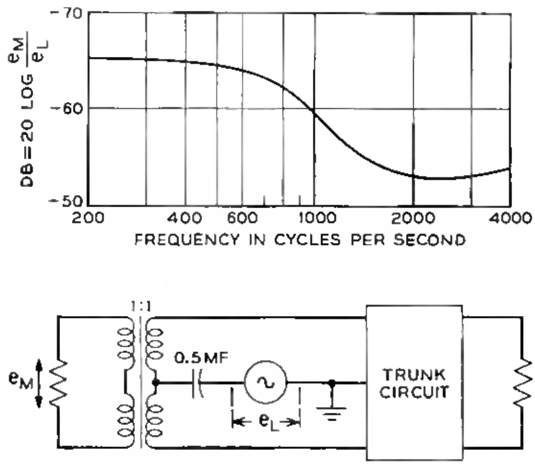


Fig. 13 — Longitudinal balance of trunk transmission circuit. Balance in db = 20 log [$e_{metallic}/e_{longitudinal}$] when measured as shown.

cuits, a number of other transmission features of importance are included in No. 1 ESS. The tone generators which supply signals to the tone circuit in Fig. 7 are balanced to ground and present a very high return loss when measured against 900 ohms + 2.14 mf. The level of these tones is closely controlled. Similar balance and return loss properties will be found in other service circuits, including the customer dial pulse receiver and interoffice transmitters and receivers.

A transistorized conference circuit is available to permit up to four persons to hold a joint conversation. Each input to this circuit has a separate appearance on the switching network so that full access to all lines and trunks is available. Modified versions of the conference circuit are used with certain operator-controlled calls and coin-zone dialing applications to permit the operator to split and hold the parties and talk to either or both without impairing transmission.

3.3 *Switching and Transmission in Trunk Circuits*

When the switching principles described in connection with the service circuits are combined with the basic transmission package, a small but versatile group of trunk circuits results. Three are chosen for discussion in Figs. 16, 17 and 18. Just as service circuits are made up of basic building blocks such as pulse correction circuits, detectors, etc, which are connected singly and in groups as needed, so the transmission package

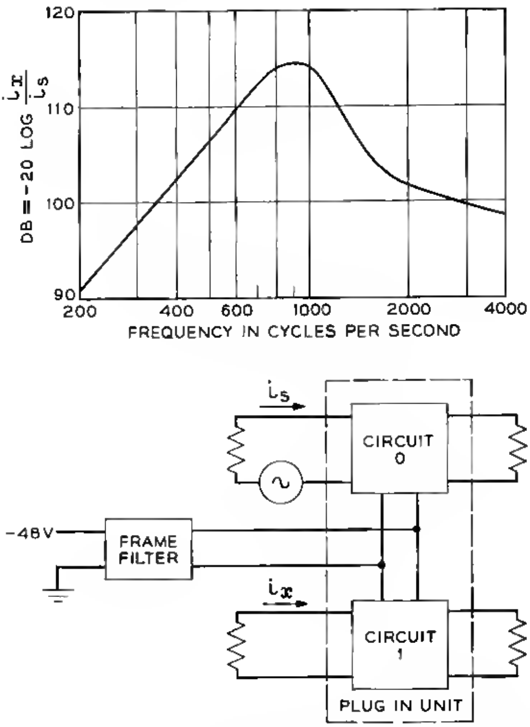


Fig. 14 — Attenuation of crosstalk signal i_x in ckt. 1 over input signal i_s in ckt. 0 when coupling is via common frame filter and power wiring as well as adjacency of components on mounting unit.

can be thought of as supervisory bridges, coupler, loop compensation network, idle circuit termination, and the like. In addition to arranging these components in various ways for local and tandem calls, relays in trunk circuits can bypass them all and connect a pair of conductors with no series or shunt components to the switching network. This permits direct connection to digit transmitters and receivers as required; dial or revertive pulses as well as multifrequency and panel call indicator signals can bypass the transmission elements in the trunk circuits.

Bypass and tandem requirements dominate in establishing the switching design of most trunk circuits. The general idea is to have only two supervisory bridges (one for each trunk) and one coupler in any tandem connection. To achieve this, three rules are applied:

(1) Operator trunk circuits always retain the coupler. In all trunk

circuits the coupler contains a transformer, which is usually a 1:1 device in the 900-ohm ESS office. However, switchboards usually use 600-ohm circuits and, if a switchboard is located in the same building as the ESS, one trunk circuit is shared by both. Because of this frequent need for impedance transformation in operator trunk circuits, the coupler always remains.

(2) Incoming (nonoperator) trunks must frequently be connected to operators for intercept service, etc. Since operator trunk circuits always contain couplers, incoming trunk circuits never retain couplers on a tandem connection.

(3) Outgoing (nonoperator) trunks may be seized by either operator or nonoperator incoming trunks. Since operator trunk circuits always contain the coupler and incoming circuits never contain it, two separate tandem states are provided in outgoing trunk circuits, one with and one without the coupler.

Comparison of the Karnaugh maps of the incoming and outgoing trunk circuits shows that the same number of states is used in each circuit. This points up another reason for rules (2) and (3) above. The incoming trunk circuit must transmit a reverse battery signal to the calling office when the called customer answers, so that the calling office can start charging. This reversal can be made only by a signal distributor operation. Thus the incoming trunk circuit needs two talking states, one for charge and one for free, in both the tandem and local conditions (four states in all). On the other hand, the outgoing trunk circuit detects the battery reversal from the distant office by means of a diode-polarized ferrod sensor in the scanner which transmits the information to the

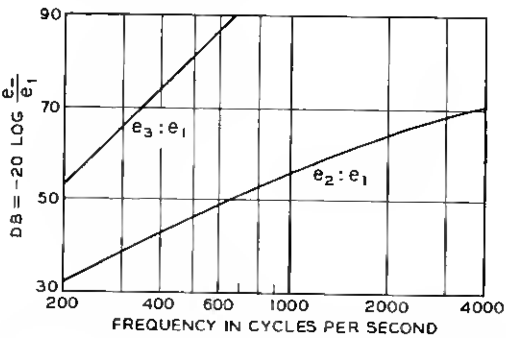
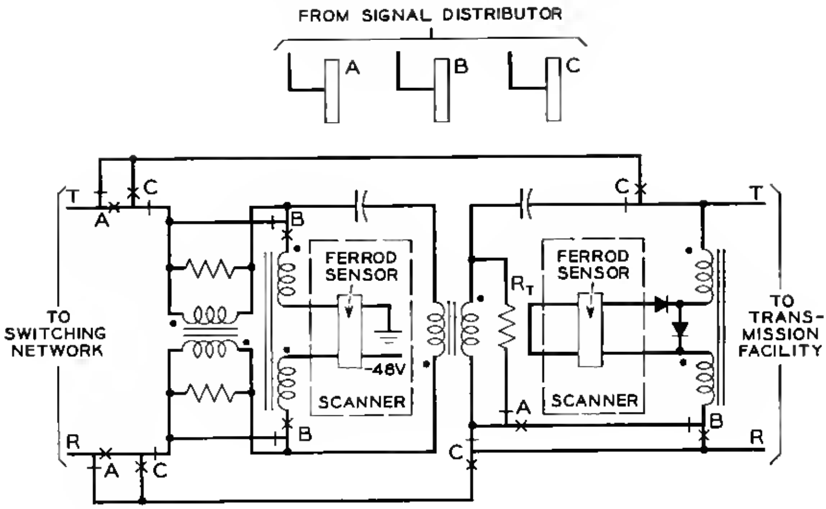


Fig. 15 — Attenuation of noise by frame filter (e_2:e_1) and combined attenuation due to filter and noise canceling transposition (e_3:e_1). See Figs. 3 and 9 for circuits and definitions of e_1, e_2, and e_3.



B OPERATED

A OPERATED

0 IDLE	1 TANDEM WITH COUPLER IN THIS CIRCUIT	3 TALK, CALL ORIGINATED LOCALLY	2 HOLD LOOP, OPEN NETWORK PATH
4 BYPASS FOR SIGNALING AND TESTING	5 NOT USED	7 TANDEM, COUPLER IN INCOMING TRUNK CIRCUIT	6 TRANSITION

C OPERATED

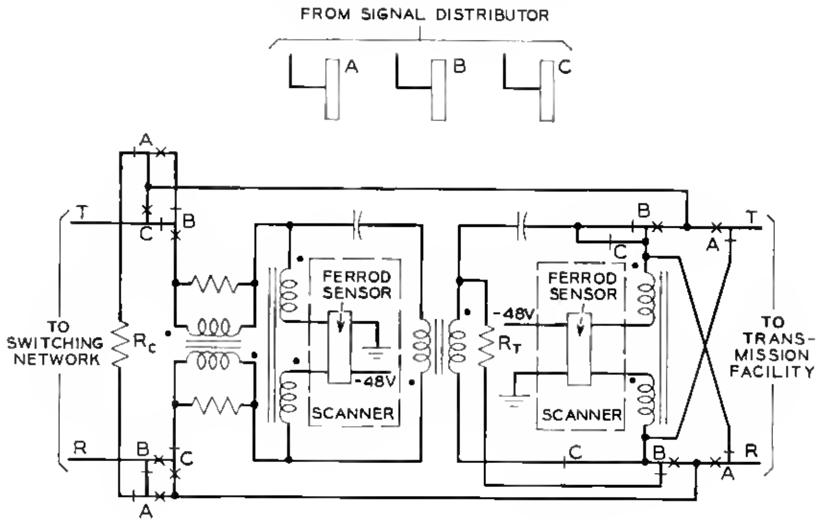
SEQUENCE	STATE NUMBERS
LOCAL ORIGINATED CALL	0-4-6-2-3-2-0
TANDEM-(COUPLER IN THIS CIRCUIT)	0-4-6-2-3-1-0
TANDEM-(COUPLER IN INCOMING TRUNK CIRCUIT)	0-4-6-2-3-7-3-2-0

Fig. 16 — Outgoing trunk circuit.

central processor. Thus no differentiation between charge and free talking states need be made by signal distributor operations. This factor makes it easier to provide the two tandem states in the outgoing trunk circuit than in the incoming trunk circuit. With this background discussion, the operation of the circuits in Figs. 16, 17, and 18 should be self-explanatory.

IV. DIGIT TRANSMITTERS AND RECEIVERS

Digit transmitters and receivers, unlike the registers and senders of crossbar and panel offices, are relatively simple circuits. In No. 1 ESS, all digit registration and all control of office operation are carried out by the central processor. Thus, the only major function left to be performed by transmitters and receivers is translation from the "language" of trunks and lines to the "language" of the central processor.



B OPERATED

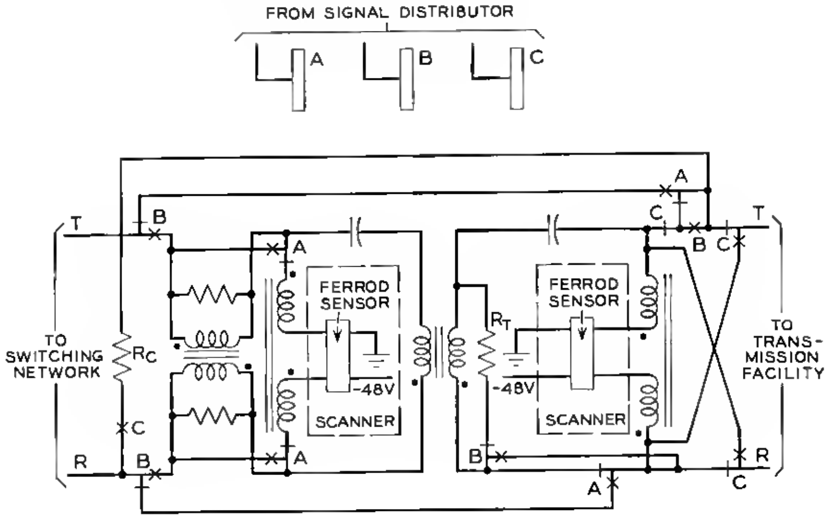
A OPERATED

0 MONITOR FOR ORIGINATION, HOLD	1 BYPASS FOR SIGNALING	3 TALK LOCAL CHARGE	2 TALK LOCAL FREE
4 NETWORK CONTINUITY CHECK USING R_C	5 NOT USED	7 TANDEM CHARGE	6 TANDEM FREE

C OPERATED

SEQUENCE	STATE NUMBERS
LOCAL TERMINATED CALL	0-1-0-2-0-2-3-2-0
TANDEM CALL	0-1-0-2-6-7-6-2-0

Fig. 17 — Incoming trunk circuit.



B OPERATED

A OPERATED

0 IDLE, MONITOR FOR ORIGINATION	1 BYPASS FOR SIGNALING	3 TANDEM (OFF-HOOK)	2 TALK LOCAL (OFF-HOOK)
4 SEIZE AND HOLD	5 NETWORK CONTINUITY CHECK USING R_C	7 TANDEM (ON-HOOK)	6 TALK LOCAL (ON-HOOK)

C OPERATED

SEQUENCE	STATE NUMBERS
LOCAL ORIGINATED CALL	0-4-6-2-0
LOCAL TERMINATED CALL	0-1-0-2-3-2-0-2-6-2-0
INCOMING TANDEM CALL	0-1-0-4-5-7-3-2-0
OUTGOING TANDEM CALL	0-4-5-7-3-1-0

Fig. 18 — Operator trunk circuit.

No. 1 ESS, with its network capable of transmitting dc signals at relatively large voltage and current levels (compared with speech signals), permits direct connections between trunks and specialized circuits designed for various types of pulsing. Trunk circuit bypass states remove all series and shunt impedances just as the cutoff contacts in the

line circuits do. By concentrating pulsing operations in a relatively small number of specialized circuits, control operations are greatly simplified. For instance, only a few scan points need to be scanned at a high enough rate to detect dial pulses, and only a small number of central pulse distributor outputs are required for the fast and frequent operation of outpulsing devices.

For customer lines, No. 1 ESS provides customer dial pulse receivers as described in Section III. TOUCH–TONE signaling[7] can be added by associating a TOUCH-TONE detector with a customer dial pulse receiver. A combination of the two circuits is called a TOUCH-TONE receiver, and such a combination can receive both conventional and TOUCH-TONE pulsing. The TOUCH-TONE detector is completely transistorized and converts ac tones generated in customer subsets to dc signals required by ferrod sensors in the scanner.

For trunk signaling, transmitters and receivers for dial pulsing, revertive pulsing and multifrequency pulsing are available. In addition, a panel call indicator transmitter has been designed. The multifrequency and dial pulse receivers and the revertive transmitter all detect pulses of the particular type from the transmission facility and convert such pulses to scanner signals. The multifrequency receiver is the most elaborate of the three, and, like the TOUCH-TONE detector, is transistorized.

The multifrequency, dial pulse and panel call indicator transmitters and the revertive receiver all use devices operated by the central pulse distributor to gate out suitable pulses. The multifrequency transmitter contains two transistor oscillators and a mixer to generate the required signal, and six devices operated by the central pulse distributor to cause the oscillators to produce the proper frequencies for each digit. The circuits which send dc pulses need fewer central pulse distributor outputs for the generation of loop opens and closures or high- and low-current conditions. However, they have much longer holding times and require separate circuits to convert their dc signals to voice-frequency tones for pulsing over carrier transmission facilities.

V. EQUIPMENT CONSIDERATIONS

Trunk, junctor and service circuits are constructed from a rather small universe of devices. Just three different codes of magnetic latching relays are used in signal distributor state-switching, and fewer than ten transmission components are needed for the configurations depicted in Figs. 3 and 9. Only in the more elaborate service circuits (which are supplied in relatively small quantities) does the number of different component

types reach any appreciable size. Here several codes of transistorized circuit packs are required along with several additional types of relays.

Wire spring magnetic latching relays, although slow by electronic standards, are the practical economic choice when switching operations need not be made very quickly or often. Their ability to switch a number of leads independent of each other and the activating coil is particularly advantageous. They require no holding power and are pulsed operated and released by signal distributors; the coils of all three codes have identical electrical properties.

Junctor circuits and a great many trunk and service circuits contain only latching relays and transmission components. A new series of inductors and transformers was developed for No. 1 ESS, and small mylar-foil capacitors were adopted. Uniformity in component size — all relays and transmission devices are four inches tall or less — makes possible very compact equipment arrangements.

With central processor control, circuits as well as components exhibit uniformity. As can be seen from Figs. 3, 7, 16, 17, and 18, the central processor sees all junctor circuits and many trunk and service circuits in terms of two scan points and three signal distributor points or less. Such standardization led to the development of a family of plug-in junctor and trunk units, using the simple angle-type sheet metal chassis shown in Fig. 19, which mates with the same connector used by printed wire boards.[8] Such units are surface wired with wire-wrap connections. In a typical office, about three-fourths of all trunk and service circuits are plug-in and mount on universal trunk frames as shown in Fig. 20. Junctor frames are similar in appearance. The center bay contains the scanner and signal distributor; the bays on the left and right contain positions for plug-in units. Wiring within each bay is highly standardized as a result of fixed plug-in connector terminal assignments and is completed at the factory.

Sixty-four equipment units (or up to 128 circuits) plug into a standard 26-inch-wide frame. This density is made possible by the use of seven inches of space in front of the frame rather than the four inches conventional mounting would have allowed. The actual mounting area on a frame is only eleven square inches per circuit.

In addition to saving space, a high density of circuits makes possible economical scanner and signal distributor design. Per-point cost drops with increasing size in both circuits, and high circuit densities also produce short lead lengths.

Digit transmitters, receivers and other trunk and service circuits which do not fit this standardized pattern are mounted in miscellaneous

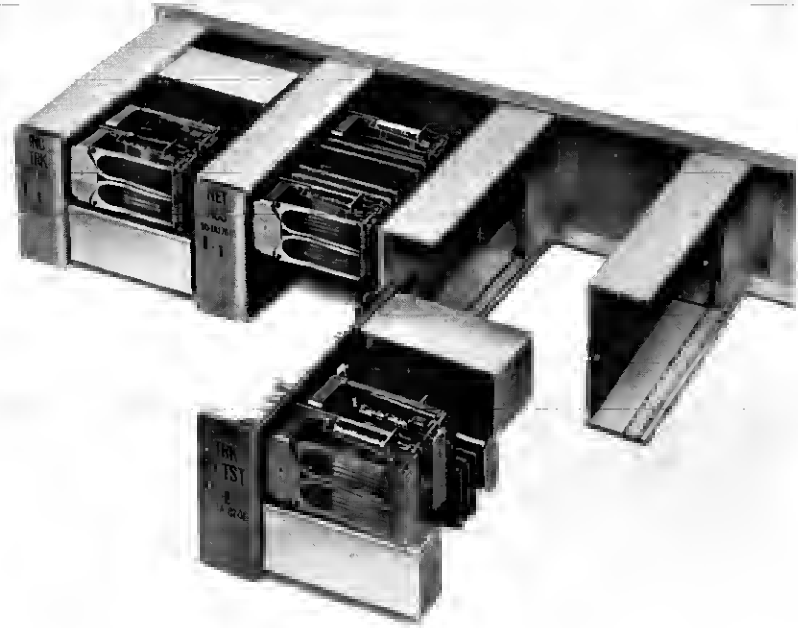


Fig. 19 — Plug-in trunk unit containing two circuits.

trunk frames. These units, typified by the pair of MF receivers shown in Fig. 21, often consist of combinations of semiconductor circuit packs, network and relays. Each unit has one or more terminal strips to simplify frame wiring (on the rear) and installer wiring (on the front).

In contrast to the plug-in units, this fourth of the trunk and service circuits requires detailed engineering to meet specific office requirements. The majority of these designs are single circuit units, although customer dial pulse receivers, TOUCH-TONE detectors, and MF receivers come two to a unit, and certain small auxiliary circuits come as many as 24 to a unit.

VI. MAINTENANCE

6.1 *Introduction*

Trunk and service circuit maintenance is based on three primary objectives: The system must (a) remove any faulty unit from customer use as quickly as possible, (b) pinpoint detected troubles to a very small

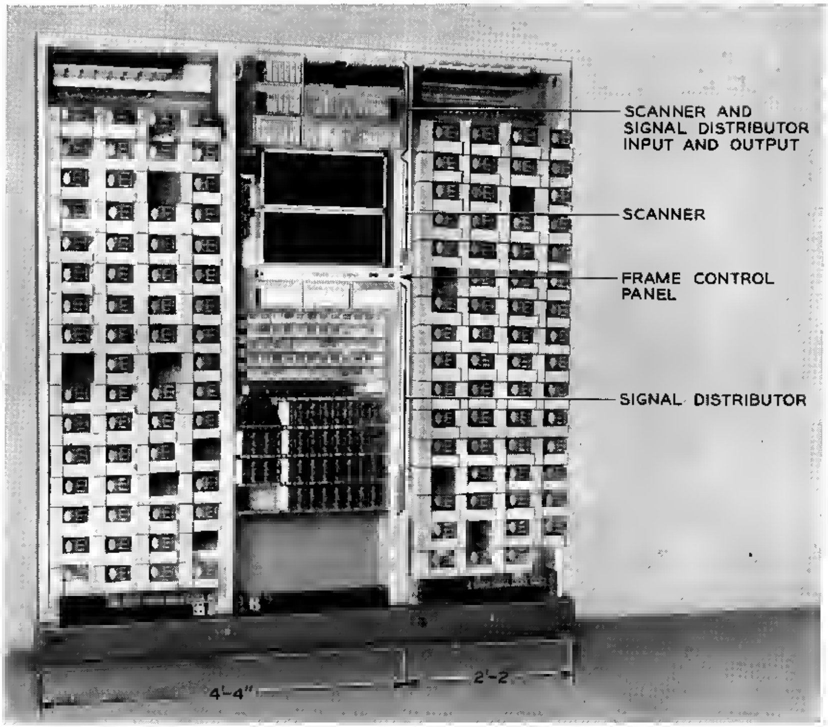


Fig. 20 — Universal trunk frame.

amount of hardware, and (c) keep the maintenance force informed using a minimum amount of teletypewriter output. To accomplish these objectives, symptoms are gathered by observing circuit and system abnormalities, analyzing the abnormalities, and drawing conclusions regarding any trouble detected. Maximum use is made of temporary memory, stored program and the switching network.

The four main phases of trunk and service circuit maintenance, consisting of trouble detection, diagnostic testing, trouble reporting, and circuit disposition, are depicted in the generalized flow chart of Fig. 22.

6.2 *Trouble Detection*

During customer calls, the system is always on the lookout for abnormalities. Holding times of digit receivers and transmitters and other service circuits are measured in the central processor to detect various stuck conditions. Up-checks and down-checks are built into every signal

distributor operation. Certain circuits contain special check states for rapid testing of large portions of the circuit. The customer dial pulse receiver and ringing circuits provide tests for certain outside plant troubles on each originating and terminating call. The transfer of supervision from one circuit to another checks network continuity and proper functioning of circuit relays.

Many call abnormalities are indications of trouble conditions which could be in one of several circuits. In these cases, various decisions are made to isolate the faulty circuit. If, for example, upon connection of a line to a dial pulse receiver an off-hook condition is not observed, the fault may lie with the receiver, the network connection, the line ferrod, or the loop. By substituting a second receiver or network path or checking the line ferrod, faults in these areas of circuitry can be deduced.

Most customer call abnormalities are indications of circuit faults; a few are the result of traffic overload conditions. Some screening is done to separate these two conditions and prevent unnecessary testing. Such screening would be used upon failure to receive start-pulsing signals from a terminating office after the originating office transmits seizure signals. Counts are kept in temporary memory for each transmitter indicating the number of times this has occurred. If the counts are evenly distributed over all transmitters, a traffic overload condition is assumed to exist. A diagnostic test on a transmitter is carried out only when its failure count is significantly higher than the failure counts of other circuits.

Outgoing trunks are treated in a similar manner. However, per-trunk memory is not available for this function and time sharing of temporary

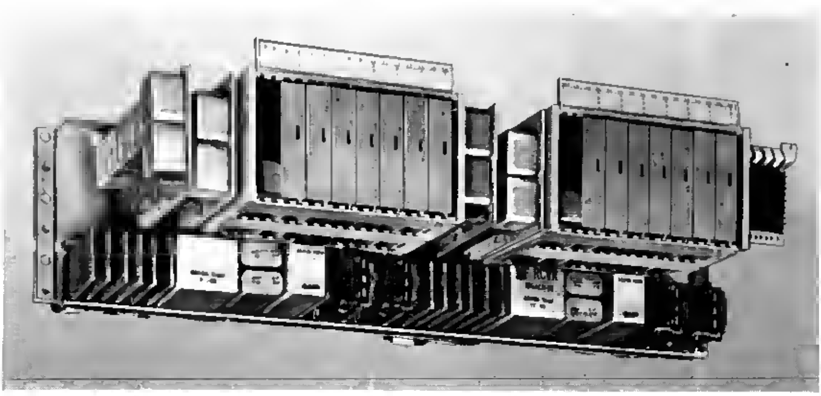


Fig. 21 — Equipment unit containing two MF receivers.

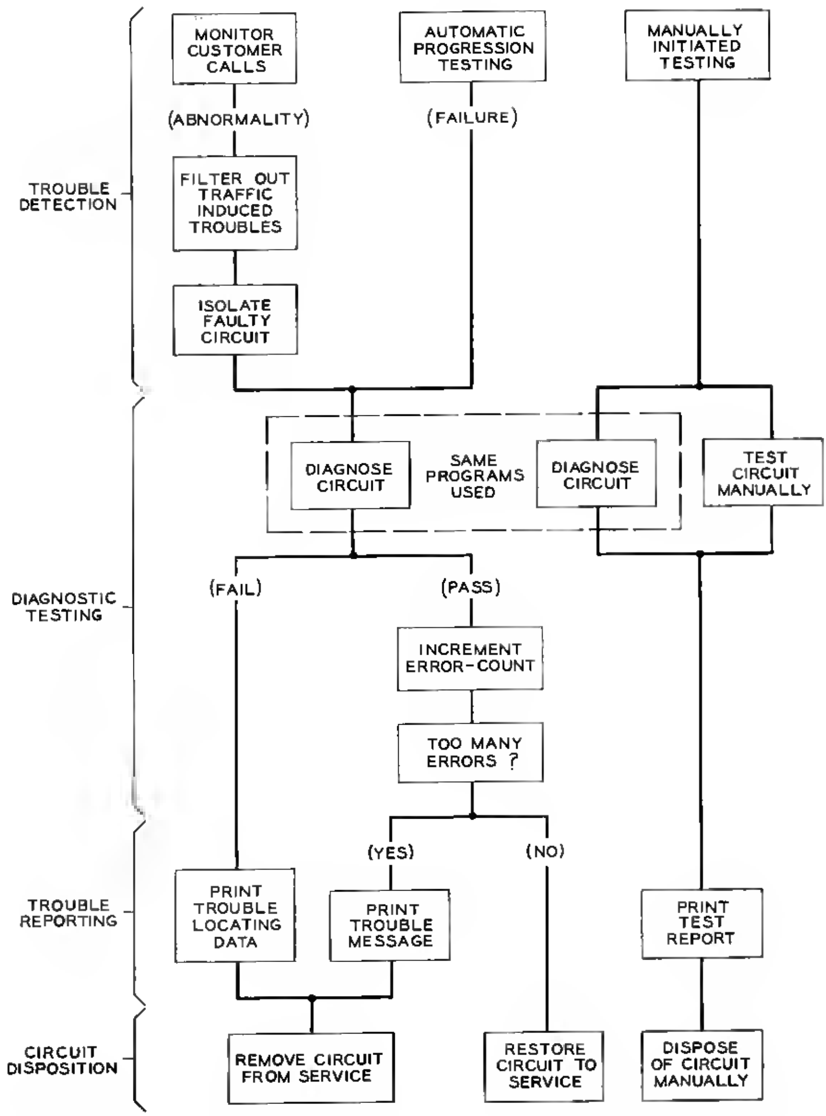


Fig. 22 — Generalized flow chart for trunk and service circuit maintenance.

memory must be used. A few memory words are temporarily assigned to one trunk group or a part of one trunk group to store failure rate information. This information is analyzed in a manner similar to transmitter failure information, preventing undesirable and meaningless testing of outgoing trunks.

While information is being gathered on one trunk group, other groups may be encountering similar difficulties. These indications are counted in a single counter for all the remaining trunk groups in the office. A sufficiently high count will cause detailed observations to be stopped on one trunk group and started on some other trunk group. Thus a small amount of memory can lead to the identification of a faulty trunk with a minimum amount of teletypewriter output for the maintenance man.

6.3 *Diagnosis*

In general, a number of small test segments is needed to test any trunk or service circuit. Each program test segment requires a circuit or combination of circuits to carry out normal functions. Trunk, service, and test circuits, as required, are connected together through the switching network. Correct circuit operation generates a particular set of data, which the central processor stores in temporary memory. If a circuit should malfunction during the test segment, a different set of data, which can be thought of as a "trouble symptom," would be generated. Rather than stopping upon receipt of the first trouble symptom, all test segments are carried out. Much more can be learned from a complete set of symptoms than from just the first one encountered.

When all test segments are complete, a large quantity of data has been accumulated. Diagnosis is completed by comparing these data with a block of "all tests pass" data stored in the permanent memory. Failure to match means a fault exists in the circuit under test, and the test data stored in the temporary memory are printed out for the maintenance man. He can isolate the faulty components through use of a dictionary which was prepared by simulating faults in the circuit under test and recording the trouble symptom.[9]

Many tests are available for customer lines, trunks and service circuits following the basic pattern outlined above.

Outgoing trunks to distant offices can be checked automatically for supervision and digit pulsing as well as tone returned from the distant office. This is done by placing program-initiated and controlled test calls to test lines in the distant office and detecting the response signals from them.

Incoming trunks can be tested for permanent signals, called customer supervision and ability of trunk circuit relays to change state; such tests are made without test calls being initiated by the distant office. Outgoing operator trunks can be tested with the aid of suitable recorded announcements which inform the operator that a test is being made, that the system expects her to take a prescribed set of actions, and that the system will interrogate the trunk circuit responses.

Tests of the type described above are carried out in response to call processing failures. The test programs are also used for automatic trunk progression testing; a control program is added to indicate to the diagnostic programs which circuits are to be tested and in what order. When a trouble is indicated on the first pass through the diagnostic program, the control program treats this as a trouble detected; the diagnostic program test is then repeated. Failure of the second pass causes removal of the faulty circuit from service and a trouble print-out to the maintenance man.

Safeguards are included to prevent the automatic removal of too many circuits from service. Whenever two successive automatic tests of the same type fail, any common test circuitry is checked before normal testing is resumed. Also, the system cannot automatically remove from service more than a fixed percentage of the circuits in any group.

6.4 *Error Analysis*

When a trouble is detected by the failure of a check during call processing or progression testing but a subsequent diagnostic test yields an "all tests pass" result, the system records an "error" for the circuits under test. Errors can be caused by transient noise pulses, unstable circuits, marginal conditions not simulated during diagnostic tests, dirty relay contacts, and the like. Maintenance error counts are kept on a limited number of trunks at any given time. These running counts are updated and compared to removal-from-service criteria. If this comparison shows the error rate to be too high, the trunk is removed from service. When a removal from service occurs, the maintenance man is notified and given the trunk circuit identity. If any trunk does not accumulate enough errors to warrant removal from service, its space in the error counting facility is given to a new trunk where an abnormally high error rate is suspected. Periodically, the maintenance man is given a summary error count to indicate the level of performance of these circuits.

6.5 *Manual Test Control*

The trunk and line test panel (T&LTP) in the master control center,[10] shown in Fig. 23, makes possible another battery of tests. Customer lines, trunks and service circuits can be connected to the master control center by using TOUCH-TONE callers on a master test line. Lines having permanent signals can be connected by a program handling a temporary memory queue which contains the identity of lines awaiting attention. Manual keys control the access circuitry; through additional keys, the line, trunk or service circuit in question is connected to voltmeter or transmission test circuits or jacks for portable test equipment. The TOUCH-TONE caller can also be used to control the setting of relay states in trunk or service circuits; this permits manual troubleshooting.

The TOUCH-TONE caller can be used to specify a trunk or service circuit on which the maintenance man wishes to run a diagnostic program once or repeatedly. Repeated testing is stopped at the end of a complete diagnostic program test if any failure occurs. A teletypewriter message gives the number of times the diagnostic program was completed before failure and the usual diagnostic information on the failed test. If a circuit to be tested is busy, a camp-on feature notifies the maintenance man when it is available.

6.6 *Summary*

Extensive checking during normal customer calls leads to rapid trouble detection. Diagnostic test programs remove faulty units from customer service. Gathering meaningful data during diagnosis pinpoints troubles to a small amount of equipment. Screening before and after diagnostic tests are performed, coupled with the gathering of meaningful diagnostic data, helps keep the maintenance force informed with a minimum of teletypewriter output. Diagnostic programs are available for each type of trunk or service circuit; these programs can be used in many ways both by the machine and the maintenance man. With these aids, the maintenance man should have little difficulty in isolating troubles. Replacement of defective circuits is facilitated by the extensive use of plug-in units.

VII. CONCLUSIONS

The line, trunk, junctor and service circuits in No. 1 ESS have been designed to take full advantage of stored program techniques.

Fig. 23 — Trunk and line test panel in the master control center.

Because the hardware has been reduced to a minimum, the great majority of changes which may eventually be required can be made entirely within the program itself. The isolation of functions in service circuits permits the addition of new features or the deletion of old without changing anything except the service circuits involved and the translation information in memory. Programmed maintenance techniques make possible equally simple changes in testing. With this flexibility, No. 1 ESS should meet successfully the challenges of the future.

VIII. ACKNOWLEDGMENTS

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